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THESIS

QUANTIFYING THE PROBABILITIES OF SELECTION OF SURFACE WARFARE OFFICERS TO EXECUTIVE OFFICER

by

Jeffrey M. Sirkin

September 2006

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QUANTIFYING THE PROBABILITIES OF SELECTION OF SURFACE WARFARE OFFICERS TO EXECUTIVE OFFICER

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ABSTRACT

This thesis seeks to identify factors affecting the probability of selection of a Surface Warfare Officer (SWO) to Executive Officer (XO) in the U.S. Navy. Selections to XO are made by a board that meets annually. Because a candidate is considered for selection in up to three consecutive boards, the possible outcomes in this process are selection to XO in one of three annual boards, failure to be selected to XO in the third board, or attrition from the process between boards. Using data on the board's selections over a three-year period (2002–2004) a hazards-based logistic regression model is developed to estimate the probabilities associated` with a candidate's disposition based on his or her career profile. The model confirms that a candidate's recent fitness and evaluation report (FITREP) is the single-most-important factor affecting selection. Additionally, officers who have completed a tour in Washington D.C. or at the Bureau of Naval Personnel have higher probabilities of selection than do those who have completed other shore tours. But when an officer receives a poor FITREP, the probability of selection is low, regardless of other factors. A nonparametric statistical analysis is used to confirm these findings.

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LIST OF ACRONYMS

ADM	Admiral
BUPERS	Bureau of Naval Personnel
CNP	Chief of Naval Personnel
CNPC	Commander Navy Personnel Command
CO	Commanding Officer
DLAB	Defense Language Aptitude Battery
DLI	Defense Language Institute
DH	Department Head
DIVO	Division Officer
EMPRS	Electronic Military Personnel Record System
ENS	Ensign
FITREP	Fitness Report & Counseling Record
GLM	Generalized Linear Model
JPME	Joint Professional Military Education
LCDR	Lieutenant Commander
LDO	Limited Duty Officer
LRT	Likelihood Ratio Test
MILPERSMAN	Naval Military Personnel Manual
MHLR	Multistage Hazard Logistic Regression
NOB	Not Observed
NPC	Navy Personnel Command
OAIS	Officer Assignment Information System

OCM	Officer Community Manager
OSR	Officer Summary Record
PSR	Performance Summary Record
PYG	Promotion Year Group
NPC	Navy Personnel Command
RL	Restricted Line
SWO	Surface Warfare Officer
URL	Unrestricted Line Officer
XO	Executive Officer

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EXECUTIVE SUMMARY

The United States Navy Surface Warfare Officer (SWO) community selects officers for Executive Officer (XO) by means of an administrative screening board. This board convenes annually to select officers from a pool of eligible candidates. Officers are eligible for selection to XO within a three-year time window: They may be selected on their first, second, or third look; or they may not be selected for XO during their career. Conversely, the selection board reviews candidates of whom the majority are drawn from three successive promotion year groups (PYGs).

This thesis examines the career profiles of officers from three PYGs (2002 through 2004) to identify factors that dispose a candidate either positively or negatively to selection to XO. The disposition of an officer in the selection process can be represented as one of the following six time-ordered outcomes: (1) selection on first review; (2) attrition after first review but before second review; (3) selection on second review; (4) attrition after second review but before third review; (5) selection on third review; and (6) not selected for XO. Data from three selection boards, which convened in 2002, 2003, and 2004, are analyzed using a probability model that incorporates explanatory variables, and that recognizes the time-sequential nature of the selection process. The model allows for the fact that only one of the cohorts (PYG 02) had completed the full three-year selection process; those not selected in the other two cohorts (PYG 03 and PYG 04) remained eligible for selection in a future board (in 2005 or 2006). The model also adjusts for attrition that occurred between selection boards, which was not directly captured by the data. Additionally, nonparametric statistical techniques are used to explore relationships between the explanatory variables and the probability of selection. .

Explanatory variables derived from the career profiles of officers in the PYG 02, PYG 03, and PYG 04 cohorts were used to model the probabilities that an officer would progress to the next step of the time-sequential selection process. These variables include ratings from the officers' fitness and evaluation reports (FITREPs) at O3 (pay grade), whether the officers served a tour of duty in Washington D.C. or at the Bureau of Naval

Personnel, and on which coast (East, West, or both) the officer served during his or her department head tour. Other variables that were considered include whether an officer is nuclear-trained, has completed a Master's Degree, is prior enlisted, and has completed Joint Professional Military Education (JPME).

Several explanatory variables emerge as important in modeling an officer's probability of selection for XO. The most prominent of these is the officer's FITREP rating at the O3 pay grade. Having a good FITREP does not guarantee selection to XO, but a poor FITREP is a difficult obstacle for a candidate to overcome. Other factors in an officer's career profile also contribute significantly to the probability model, but none carries more weight than the FITREP rating. Nonparametric statistical tests also confirm the finding that the O3 score is the most influential attribute leading to an officer's selection or non–selection to XO.

I. INTRODUCTION

The Surface Warfare Officer (SWO) community is responsible for the manning of all US Navy surface ships. It manages the surface community, distributes its officers in accordance with the mission of Navy Personnel Command (NPC) PERS-4 (Career Management Department), and is responsible for all surface-warfare-related manpower issues. PERS-4 is directed by a Navy flag officer and is administratively and operationally in charge of the SWO community (PERS-41) for all assignment and management issues. PERS-41 is directed by a Navy Captain and is responsible for the assignment of officers, placement of officers (ships manning), and the management of the community (number of officers). For the purposes of this thesis, the masculine pronoun "he" is used, but SWOs can be male or female.

The SWO community is part of the Unrestricted Line Officer (URL) community. Officers in the Navy are categorized into one of five general types: URL, restricted line (RL), staff corps, limited duty officers (LDO), and warrant officers. Each of these is described briefly below:

- Unrestricted Line Officer: As the name suggests, a URL officer is one who is not restricted in the performance of his duty. URL officers are authorized to lead sailors and command ships, submarines, aviation squadrons, special operation, and special warfare units. To command a commissioned United States Navy ship, an officer must be a member of the URL community and be eligible for command-at-sea (Department of the Navy, 1990). Command-at-sea refers to a URL officer who is the Commanding Officer (CO) of a deployable ship, aviation squadron, or other sea-deployable unit.

- Restricted Line officer: RL officers support URL officers in activities that require specialized training and skills in areas that align with operational requirements. The command of an RL officer is restricted to areas directly related to the officer's area of expertise.

- Staff Corps Officer: Staff corps officers are dedicated to provide support services to operational units. Staff corps officers include those in the Supply Corps, the Medical Corps (doctors), and the Nurse Corps.

- Limited Duty Officer: LDOs are either line or staff technical managers who are limited to performing duties related to their former enlisted ratings, generally up to the department head level.

- Chief Warrant Officer: CWOs are either line or staff technical specialists who are limited to performing duties related to their former enlisted ratings.

As of 2006, the SWO community is a diverse group of 7,522 officers. Approximately 85.6 percent are male and 14.4 percent are female. However, from the rank of Lieutenant Commander (LCDR) through Admiral (ADM), the community is approximately 97.2 percent male and 2.8 percent female (Navy Personnel Command PERS-41, 2006).

A. AT-SEA CAREER PROGRESSION OF A SWO

As a newly commissioned officer, a SWO starts his career serving as a division officer (DIVO) on a ship. He will serve as a division officer for two tours, lead a small division of sailors, and report to a Department Head (DH). He will also learn the fundamentals of surface warfare and attain qualifications as a SWO during this period. The division officer tours are approximately 42 months.

A SWO will return to sea at approximately the eight-year point and will serve two tours as a DH. A department head is in charge of one of the various departments on the ship and reports to the Executive Officer (XO). The DH tours are approximately 36 months.

Upon completion of the DH tours, screened SWOs will serve a tour as an XO afloat. All Navy ships have one XO who is responsible for the administration of the ship. The XO reports directly to the CO and is second-in-command of the ship. The length of this tour varies, but is typically at least eighteen months.

Finally, screened officers will serve as a CO afloat. The CO of a ship is responsible for all aspects of the ship and reports directly to the group commander. The length of this tour varies and is a function of the number of SWOs in a particular year group.

To be assigned as a CO on a commissioned US Navy surface ship, an officer must follow a defined career path starting at the rank of Ensign (ENS). The following chart illustrates the nominal career path of a SWO in relation to his years of service:

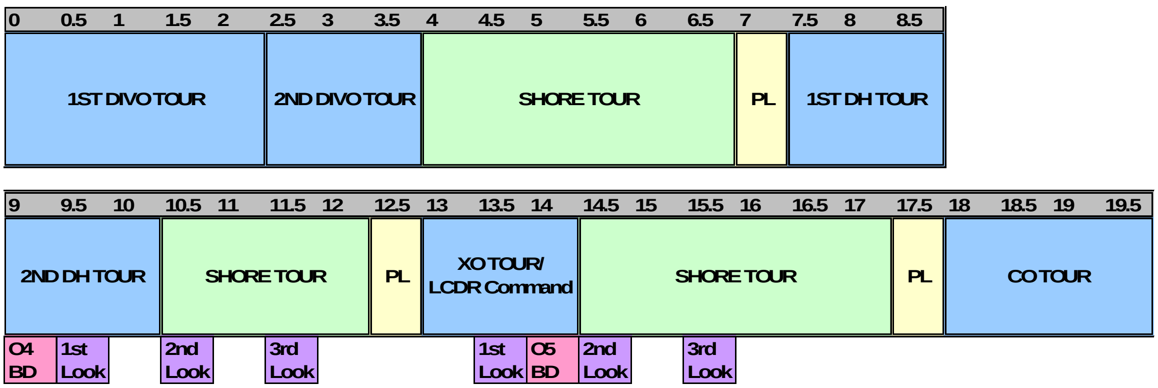

Figure 1. SWO Career Path (From: Navy Personnel Command PERS-41 Senior SWO Mentoring Brief, 2006).

The O4 board represents the time in a SWOs career where he will be eligible for promotion to the O4 pay grade. The boxes titled "1st Look," "2nd Look," and "3rd Look" represents the times in a SWOs career at which he becomes eligible for administrative screening to XO and CO. The administrative screening to XO is represented first and is the primary focus of this thesis. The O5 board represents the time in a SWOs career where he will be eligible for promotion to the O5 pay grade.

B. FOCUS OF RESEARCH

This thesis seeks to identify factors in a SWO's career profile that affect the likelihood of his being selected for XO by an administrative selection board. A selection board is comprised of people making subjective assessments, within the framework of a rules-driven process.

This thesis focuses on answering the following questions:

- How important is performance at sea to being selected to Executive Officer?
- What is the probability that a Surface Warfare Officer will be selected for Executive Officer by the first selection board, the second selection board, the third selection board, or that he will not be selected?
- Which factors in a Surface Warfare Officer's career profile improve his chances for selection to Executive Officer?
- Which factors in a Surface Warfare Officer's career profile reduce his chances for selection to Executive Officer?

With answers to these questions, an assignment officer (detailer) will be able to direct the career path of a SWO and best prepare him for selection to XO.

II. BACKGROUND

A. LITERATURE REVIEW

Two previous Naval Postgraduate School Master's theses consider how graduate education affects selection or progression through the use of statistical models to estimate probabilities. Fuchs (1996) describes the effect of graduate education on promotion and CO/XO screening in the SWO community. Fuchs uses a PROBIT model to quantify the effect of graduate education on an officer's probability of promotion. A PROBIT model used the standard normal distribution function to describe the probability of success (e.g., promotion) as a function of explanatory variables (Montgomery, 2001).

Fuchs (1996) finds that graduate education has a positive effect on an officer's probability of promotion. Officers who are selected for and complete graduate education are more likely to be successful earlier in their career, and they are more likely to screen for career milestones such as commanding officer (CO) and executive officer (XO). An important difference between the study by Fuchs and the present thesis is that Fuchs only considers the effect of graduate education, while this thesis considers a broader set of explanatory variables, such as having completed a Washington, DC or BUPERS tour, and whether the officer has completed Joint Professional Military Education (JPME).

The thesis by Wong (2004) develops a logistic regression model to predict whether a student is likely to graduate in a particular course of instruction (language) at the Defense Language Institute (DLI) in Monterey, CA. Variables such as gender, whether a student's program of study has been realigned, Defense Language Aptitude Battery (DLAB) scores, and armed forces service components are included. Wong's model estimates probabilities of graduation in different language categories. Wong finds that higher DLAB scores and not having been realigned are traits that are favorable to predicting graduation (Wong, 2004).

B. SELECTION BOARDS

Administrative selection boards in the U.S. Navy are convened and executed in accordance with a published precept letter. A precept letter, signed by the Commander, Navy Personnel Command (CNPC), defines the procedures of the board. Board members

take an oath to follow the guidance of the precept and to not disclose any of the board's proceedings without approval of the Chief of Naval Personnel. Each board consists of one President, a variable number of voting board members, one recorder, and a variable number of assistant recorders.

All board members vote for each candidate by issuing scores that express their belief in the suitability of the candidate for the position under consideration. These scores assume one of five possible values: 0, 25, 50, 75, 100, where any vote greater than zero is considered to be a "yes" vote. After each vote, the number of yes votes and the confidence-level percentage are announced and recorded. The board then votes on which officers to tentatively select and which officers to remove from further consideration based upon the distribution of confidence vote scores. The process is then repeated with the remaining records until all selections have been made. The following section explains the process in more detail.

1. Process of SWO XO Selection Boards

After board members have been sworn in, the candidates' records are divided among the board members for review, with each candidate being reviewed by the individual board member to whom his record was assigned. During this review, a board member has access to an officer's Officer Summary Record (OSR), Performance Summary Record (PSR), and supplementary information, such as letters that the candidate may have submitted to the President of the board. Each board member assigns a quantitative "grade" to the record based upon an individual's traits and qualifications. After all records have been reviewed and graded by the assigned board member, the board retires to the "tank" for deliberations. A tank is a board space that has chairs with a secret hand voting system attached to it, large video monitors that are used to brief officer's records, and an electronic pointing system that is used by board members to amplify certain traits in an eligible officer's record.

Selection board deliberations occur in one of the three "tanks" at NPC. All aspects of their deliberations are held in secrecy unless disclosure is approved by the Chief of Naval Personnel.

During deliberations, the records of officers who are eligible for selection to XO are presented on a video monitor by the board member who was assigned to review his record. During the briefing process, the assigned board member announces his quantitative grade and amplifies any other information about the record that he deems relevant. This amplified information may consist of performance trends, qualifications, or any other information that is not explicitly excluded by the precept (e.g., marital status). Grades must be determined in accordance with the guidance given in the precept. After the board member has completed his brief, all board members cast their secret confidence vote. Once all votes are recorded, the board recorder announces the number of "yes" votes and the overall confidence vote score. This process is repeated until all eligible officers' records have been briefed and votes have been recorded.

After all eligible officers' records have been voted and recorded, a scatter-gram is displayed on one of the tank's video monitors, showing the distribution of the eligible officers' scores. The board President announces the number of officers that will be selected during the first round of voting, and the board decides on upper and lower cutoff scores which are used to select and to remove officers from further consideration respectively. The board then enters the "crunch" face in which it deliberates on officers whose scores fall between the lower and upper bounds.

The crunch phase repeats the review-and-voting process for officers who were neither accepted nor rejected in the first phase. In the crunch phase each officer's record is reviewed by a different board member. These records are again briefed, voted upon, displayed in a scatter-gram, and partitioned into selections, removals, or neither. This process is repeated until the number of authorized selections is reached in accordance with the precept letter (Navy Personnel Command PERS-480, 2006).

2. Authorized Selections

As noted above, the precept letter specifies the authorized number of selections. These selections are made from a three pools of candidates defined by their Promotion Year Groups (PYGs). The most recent PYG is facing the selection board for the first time. Candidates from the second-most recent PYG are facing the selection board for the second time, having been passed over for selection the previous year. Candidates from the third-most recent PYG are those who were passed over for selection the previous two

years. In the 2004 selection board, for example, the largest pool of candidates came from PYG 04 (first review), the next-largest pool came from PYG 03 (second review), and the smallest pool came from PYG 02 (third and final review). The number of selections made by the board is allocated among the three pools of candidates using the following algorithm:

- Step 1: Estimate the size of the current-year PYG after all three board reviews have been completed based upon historical continuation rates.
- Step 2: Determine an "opportunity rate" for each PYG (between 60-75 percent) and multiply this number by the estimated PYG size (number from previous step).
- Step 3: For the PYG in its first review, multiply the result of Step 2 by .50. For the PYG in its second review, multiply the result of Step 2 by .30. For the PYG in its third look, multiply the result of Step 2 by .20.

No direct evidence can be found that the board is tougher or more lenient on candidates based upon the number of authorized selections, because the board is formally committed to select the most-qualified candidates. However, in PYGs that have fewer authorized selections, there is more competition between candidates as the number of selections is lower (PERS-41, 2006).

C. SCOPE AND LIMITATIONS

This thesis develops a statistical model for estimating the probability that a SWO attains a specified outcome in the XO selection process. Possible outcomes are that the officer will be selected on his first, second, or third selection board; that the officer will not be selected for XO; and that the officer will attrite from the selection process between boards. Using data for three cohorts of SWOs, which we label "PYG 02," "PYG 03," and "PYG 04" to reflect the years in which the officers became eligible for selection to executive officer, the study examines the disposition of these officers before the annual selection boards convening in April of 2002, 2003, and 2004. These three cohorts encompass 590 officers with sufficiently complete data for use in the thesis research. Data on these officers were extracted from the Electronic Military Personnel Record System (EMPRS) and the SWO detailing office (PERS-41).

The disposition of the PYG 03 and PYG 04 cohorts before the 2003 and 2004 selection boards raises the issue of censored data. A PYG 03 officer who was not selected in 2004 may or may not be selected in the 2005 board. Similarly, a PYG 04 officer who was not selected in 2004 may or may not be selected in 2005 or in 2006. The PYG 02 cohort does not raise the issue of censoring because all officers' dispositions were settled in the three selections (2002, 2003, and 2004) that are within the scope of the thesis research. An analysis of the data must therefore take censoring into account.

Based on the data, a statistical model is developed that relates the probability of selection to XO to factors in an officer's career profile. Formally, the selection process is governed by Department of Navy policy which states, in part:

> The Department of the Navy is dedicated to equality of treatment an opportunity for all personnel without regard to race, creed, color, gender or national origin. The Navy strives to maintain a professional working environment in which an individual's race, creed, color, gender, or national origin will not limit his or her professional opportunities. Accordingly, within this board's charter to determine those officers who are best and fully qualified, you must ensure that officers are not disadvantaged because of their race, creed, color, gender, or national origin (Navy Personnel Command, 2006).

Because of the clearly-stated Navy policy, this thesis does not consider race, gender, or ethnic background of the officers as factors that affect their probability of selection to XO.

It must be recognized that attrition occurs in any personnel system observed for a period of years. The rate of attrition of SWOs during the three-year career window in which they are eligible for selection to XO is believed to be low. In this thesis attrition is defined as an officer leaving the SWO community regardless of whether he leaves the Navy or changes his occupational specialty within the Navy.

The data that were available for conducting the thesis research included officers who succeeded before the 2002 and 2003 selection boards, and all officers who were considered by the 2004 selection board. Officers in PYG 02 who were not selected in 2002 and left the SWO community before the 2003 selection board convened were not captured in the data. Similarly, officers in PYG 02 or PYG 03 who were not selected in 2003 and left the SWO community before the 2004 selection board were not captured.

Because attrition is not reflected the PYG 02 and PYG 03 cohorts, their data is incomplete. Analysis of the data must reflect this fact.

III. DATA AND METHODOLOGY

A. DATA

The data in this thesis were obtained from the Surface Warfare Officer Distribution Division (PERS-41) at NPC. The data are divided into two parts. The first part consists of biographical and career-related information that is used by selection board recorders during board preparatory work, board proceedings, and post-board work. The second part of the data were supplied by the Officer Assignment Information System (OAIS) and EMPRS.

1. PERS-41 Data

Each year, PERS-41 develops a database consisting of biographical and performance data on all officers who are eligible for selection to XO. These data include biographical information such as name, rank, Social Security Number (SSN), PYG, career milestones completed (graduate education, JPME), types of ships on which an officer served, and information that tracks an individual's status before the XO selection board (e.g. missing information, letters to the board, errors, etc). These data are compiled from existing sources and are not made available to voting board members.

2. Officer Assignment Information System (OAIS)

OAIS is the computer system used by NPC to issue orders and distribute Navy officers. OAIS records both biographical and performance data. Biographical information stored in the system includes data such as name, SSN, and dependent status. Performance data stored in the system include information such as promotion recommendations from Fitness Report and Counseling Record (FITREP), and officers' histories of assignments.

3. Electronic Military Personnel Record System (EMPRS)

EMPRS is the Navy's electronic military records database. This database contains an officer's career record, including academic transcripts, awards, and copies of FITREPs. EMPRS is one of the data systems that drives OAIS, and it is through EMPRS that data available in local databases are made available. Due to the sensitivity of data obtained from EMPRS, it is restricted to authorized users only.

4. Creation of Data Sets for Analysis

PERS-41 uses a Microsoft Access database tool to merge OAIS and EMPRS data into one database which contains biographical and performance history of queried officers.

B. REPRESENTATION OF THE REVIEW PROCESS

When a SWO becomes eligible for selection for XO, he is assigned to a PYG in which he may undergo up to three board reviews in successive years, resulting in either his selection for XO or in his failure to be selected for XO through this process. During the years between reviews, an officer may attrite from the process for various reasons. Nominally, a small but non-negligible number of officers are lost due to attrition. Each officer, therefore, may be assigned to one of six possible outcomes, which may be represented by assigning to an officer one six ordered values denoted by the variable Y:

$Y = 1$: SWO is selected for XO in his first board review.

$Y = 2$: SWO attrites from the XO selection process after his first board, but before his second board.

$Y = 3$: SWO is selected for XO in his second board review.

$Y = 4$: SWO attrites from the XO selection process after his second board, but before his third board.

$Y = 5$: SWO is selected for XO in his third board review.

$Y = 6$: SWO completes the process (three board reviews) without being selected for XO.

This process is depicted in Figure 2.

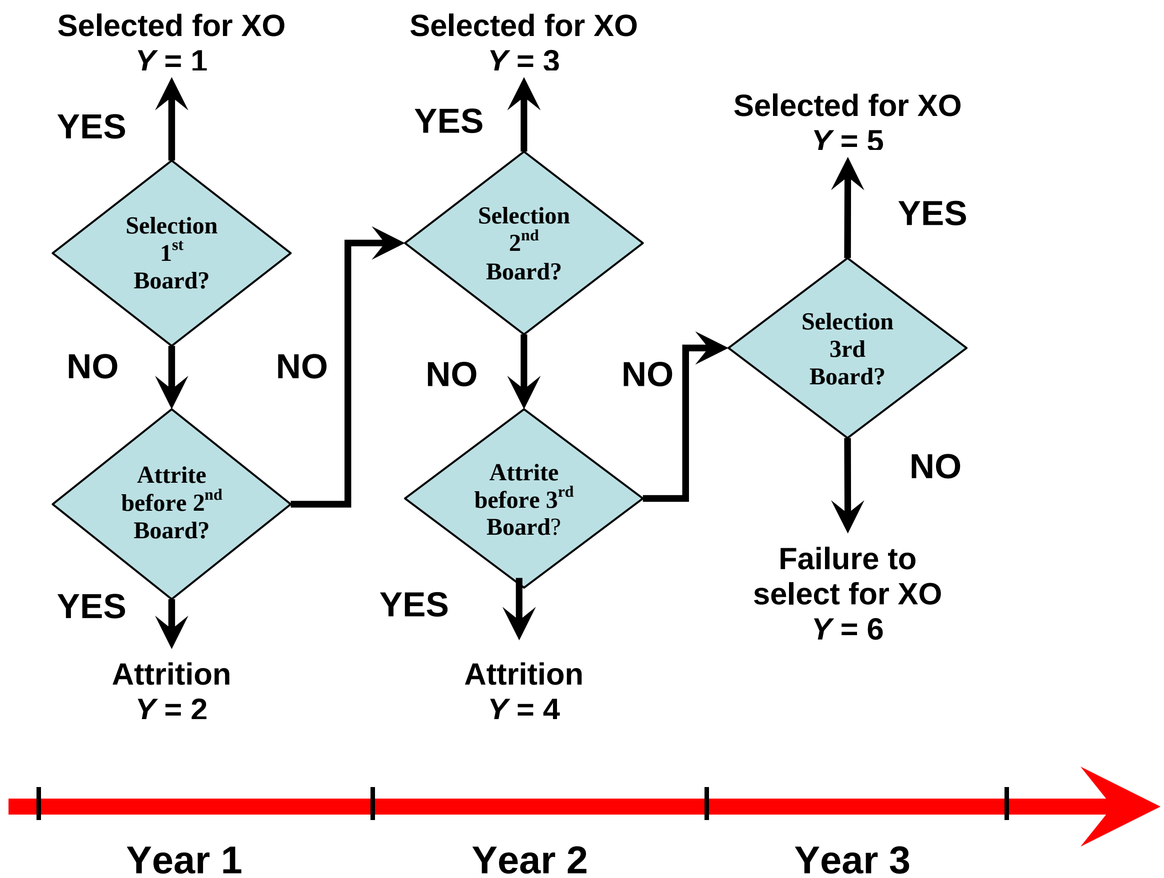

Figure 2. Outcomes of the Executive Officer Selection Process

C. STATISTICAL METHODOLOGY

An officer who is at the beginning of the selection process has a set of career attributes that may affect his probability of selection to XO over the ensuing three years. It is reasonable to treat as a random variable the outcome Y that is realized by an officer who undergoes the selection process. In this section a probability model for Y is developed.

1. Estimation of Conditional Probabilities

Let $\boldsymbol{x} = (x_1, x_2, \ldots, x_p)$ denote a vector of explanatory variables for a particular officer. The objective of probability modeling can be stated formally as follows: estimate the (conditional) probabilities

$$p(t;\, \boldsymbol{x}) = P(Y = t \mid \boldsymbol{x}), \quad t = 1, 2, \ldots, k \ ,$$

where, in the present context, $k = 6$.

For a given officer, the process of being reviewed for selection to XO may take as long as three years. During this time, information about an officer may also change. For example, an officer may receive an adverse promotion recommendation (rating) on a FITREP during the three years of the selection process that changes the probabilities of subsequent outcomes. The use of *time-dependent covariates* (Cox and Oakes, 1985) reflects the changeability of the explanatory variables with respect to time:

$$p(t;\, \boldsymbol{x}(t)) = P(Y = t \mid \boldsymbol{x}(t)), \quad t = 1, 2, \ldots, k$$

It is of interest to predict Y or to estimate its probabilities both using explanatory variables at the time an officer enters the selection process, and using explanatory variables that change as the officer continues through the selection process. As an officer enters the selection process at time $t = t_0$, a detailer will want to estimate the probability that the officer will be selected in any of the three boards for which he is eligible using information that is available at that time:

$$P(\text{select} \mid \boldsymbol{x}(t_0)) = \sum_{t=1,3,5} p(t;\, \boldsymbol{x}(t_0))$$

As the process evolves, and the officer's outcome has not yet been resolved either through selection or attrition, it is of interest to estimate the probability that the officer completes the process at the next stage. If the officer has progressed beyond stage $t-1$ of the process, it is known that his final outcome will occur at some stage t or later. Therefore, it is useful to obtain estimates of the conditional probabilities:

$$h(t;\, \boldsymbol{x}(t)) = P(Y = t \mid Y > t-1,\, \boldsymbol{x}(t)), \quad t = 1, 2, \ldots, k$$

In reliability and survival analysis, the conditional probabilities given by $h(t;\, \boldsymbol{x}(t))$, $t = 1, 2, \ldots, k$ constitute what is known as the *hazard function* of the process. Note that at time $t = 1$, $h(1;\, \boldsymbol{x}(1)) = p(1;\, \boldsymbol{x}(1))$, and at time $t = k$, $h(k;\, \boldsymbol{x}(k)) \equiv 1$. The hazard function can be used to calculate probabilities that an officer attains specified outcomes conditional on the evolution of his covariates by making use of the following inversion formula:

$$p(t;\, \boldsymbol{x}(t)) = h(t;\boldsymbol{x}(t)) \times \prod_{j=1}^{t-1} \left[1 - h(j;\boldsymbol{x}(j))\right], \quad t = 1, 2, \ldots, k$$

The probability that an officer realizes the outcome $Y = t$ should be understood to depend upon the history of his covariates $\boldsymbol{x}(t)$ up to and including time *t*, although the hazard function depends only on the value of the covariates at time *t*.

2. Hazard Function and Multinomial Outcomes

The use of statistical models for the hazard function is a standard technique in the analysis of survival and reliability data. Cox and Oakes (1985) give a thorough treatment of hazard regression, including the use of explanatory variables to model the probability (or density) that an item fails at a particular time, given that it was alive at the immediately prior time. In this thesis, "failure" refers to a SWO attaining one of the six endpoints defined for the XO selection process timeline, which includes the "desirable" outcome of being selected for XO. Cox and Oakes (1985) also treat estimation with time-dependent variables, which is relevant to this study.

Modeling of the hazard function in statistical literature usually deals with continuous response variables, such as the time to failure of an entity. In this study, the outcome variable *Y* is discrete, which takes on values in the set $\{1,2,3,4,5,6\}$. Popular models for continuous hazard functions, such as those based upon an assumption of proportional hazards, are not applicable to the discrete case, although a discrete hazards model bearing some similarity to the proportional hazards model is introduced in Cox and Oakes (1985).

The modeling strategy used in this thesis entails fitting a series of unrelated logistic regressions to the hazard function at each transition of *Y*. Taken as a whole this is referred to as the Multistage Hazards Logistic Regression Model (MHLR). The parameters of the MHLR model are estimated from data on the PYG 02, PYG 03, and PYG 04 cohorts. Let *n* denote the number of observations represented, each corresponding to an officer in one of the three cohorts. Each officer has an outcome denoted Y_i and a vector of covariates $\boldsymbol{x}_i(t)$ observed over the time frame of the selection

process. For the moment, assume that each Y_i is known, and that the data may be regarded as a representative sample of the SWO community.

The hazard function is estimated in stages. At the first stage, $h(1;\boldsymbol{x}_i(1))$ is estimated by examining all n candidates and classifying them either $Y=1$ or as $Y>1$. This simple, binary classification is modeled using logistic regression. At the second stage, $h(2;\boldsymbol{x}_i(2))$ is estimated by examining only those candidates for which $Y > 1$ is true, and a new logistic regression model is fitted based on the classification $Y=2$ or $Y>2$. This process is continued through stage $k-1$, where the candidates that are examined are those for whom $Y>k-2$, and the classification is $Y=k-1$ or $Y>k-1$ (which is the same as $Y=k$). After the hazard functions have been estimated, probabilities $p(t;\boldsymbol{x}(t))$ may be estimated by using the inversion formula on the estimated hazard functions.

The following notation explains the MHLR modeling procedure in greater detail. Let π denote any number strictly between zero and one, and define the logit function as:

$$\operatorname{logit}(\pi)=\log\left(\frac{\pi}{1-\pi}\right)$$

(In this thesis, all logarithms are natural logarithms unless indicated otherwise.) The logit function is strictly increasing, mapping $\pi\approx 0$ to values that approach negative infinity, and $\pi\approx 1$ to values that approach positive infinity. At stage t in hazard modeling, the following linear model is used:

$$\operatorname{logit}[h(t;\boldsymbol{x}(t))]=\boldsymbol{x}'(t)\,\boldsymbol{\beta}_t=\beta_{t,0}+x_1(t)\beta_{t,1}+\cdots+x_p(t)\beta_{t,p}$$

By inverting the logit function, this model is expressed equivalently as

$$h(t;\boldsymbol{x}(t))=\frac{\exp(\boldsymbol{x}'(t)\,\boldsymbol{\beta}_t)}{1+\exp(\boldsymbol{x}'(t)\,\boldsymbol{\beta}_t)}\ .$$

The logistic regression parameters $\boldsymbol{\beta}_t$ are estimated using maximum likelihood. Software for logistic regression is widely available in statistical packages such as S-Plus, Minitab, SAS, and other products.

In the MHLR model the hazard-function logistic regressions may use different sets of explanatory variables, for which coordinates of the coefficient vectors $\boldsymbol{\beta}_t$ are set

equal to zero. The total number of parameters that must be estimated across all stages of hazard modeling is given by $(k-1)(p+1)-\#\{\beta_{t,j}\equiv 0\}$, where the last quantity is the number of parameters that are set equal to zero. If $\hat{\boldsymbol{\beta}}_t$ is the estimated logistic regression parameter vector, the estimated hazard function is given by

$$\hat{h}(t;\boldsymbol{x}(t))=\frac{\exp(\boldsymbol{x}'(t)\,\hat{\boldsymbol{\beta}}_t)}{1+\exp(\boldsymbol{x}'(t)\,\hat{\boldsymbol{\beta}}_t)}$$

The estimated outcome probabilities are obtained from the inversion relationship:

$$\hat{p}(t;\,\boldsymbol{x}(t))=\hat{h}(t;\boldsymbol{x}(t))\times\prod_{j=1}^{t-1}\left[1-\hat{h}(j;\boldsymbol{x}(j))\right],\quad t=1,2,\ldots,k$$

The MHLR modeling procedure outlined above is a special case of modeling a multinomial random variable using explanatory variables. An alternative to the MHLR model is the neural-network approach taken by Venables and Ripley (1997), which the authors implement as the function `multinom` in their `nnet` library for the S-Plus® statistical computing language. In `multinom`, the outcome probabilities are expressed as follows:

$$p(t;\boldsymbol{x})=\begin{cases}\dfrac{\exp(\boldsymbol{x}'\boldsymbol{\beta}_t)}{1+\sum_{j=1}^{k-1}\exp(\boldsymbol{x}'\boldsymbol{\beta}_j)}, & t=1,\ldots,k-1\\[2ex] \dfrac{1}{1+\sum_{j=1}^{k-1}\exp(\boldsymbol{x}'\boldsymbol{\beta}_j)}, & t=k\end{cases}$$

As in the hazards-based model, the number of parameters in the `multinom` model is $(k-1)(p+1)$. Limitations of `multinom` are that it does not allow using different explanatory variables for each coefficient vector, and it does not accommodate time-dependent covariates. As a general multinomial model, `multinom` does not have the flexibility to handle situations where the outcome is a process that evolves over time.

Under some circumstances, it is desirable to simplify the hazards-based model so that the only time-dependent component in $\boldsymbol{\beta}_t$ is the constant term $\beta_{t,0}$. The coefficients for the explanatory variables remain the same across each of the hazard models, resulting

in a complete model that has many fewer $(p+k-1)$ parameters. This simplified model is described in Cox and Oakes (1985) as a discrete-time analog to the continuous-time proportional hazards model. Although this model is not explored in this thesis, it merits further study.

3. Censoring and Truncation

The three years of SWO cohort data that are available raises censoring and truncation issues that must be addressed in statistical modeling. Truncation implies missing data and censoring implies that a variable can be measured only as belonging to a set of possible values that is usually defined with respect to time. To understand these issues, each cohort group is considered separately:

- Officers in the 2002 cohort (PYG 02) were available for observation in all three selection boards (2002, 2003, and 2004) for which they were eligible. None of their outcomes was censored. Only officers who succeeded in the 2002 and 2003 were revealed, while all officers who succeeded and failed in the 2004 board were revealed. Officers who attrited from the process after failing to be selected in their first or second board were truncated from the data set. The 2002 cohort was eligible to observe the following values of Y: $1, 3, 5,$ and 6.

- Officers in the 2003 cohort (PYG 03) were available for observation in the 2003 and 2004 boards. Officers who attrited from the process after failing the 2003 board (their first board) are not captured in the data. Officers who failed the 2004 board (their second board) are captured in the data, although it is not known how these officers fared in their third board (future event). Officers with $Y=2$ are truncated from the data, and officers who failed their second board are represented by the right-censored value $Y>3$. Therefore, the 2003 cohort was eligible to observe the following values of Y: $1, 3,$ and >3 (grouping outcomes 4,5,6).

- Officers in the 2004 cohort group (PYG 04) were not affected by truncation. The outcome of every officer before the 2004 board (their first board) is known. Those who failed the first board are represented by the

right-censored value $Y > 1$. Therefore, the 2004 cohort was eligible to observe either $Y = 1$ or $Y > 1$.

The issue of right censoring does not impose difficulties for estimation under the MHLR model used in this thesis. At each stage, only officers are used who were eligible to observe the value for which the hazard function is being calculated. Right censoring at stage t results in a negative answer to the question "did the officer take on the value $Y = t$ given that $Y > t-1$?"

Truncation, however, does present difficulties which preclude fitting the MHLR model in a stage-wise manner. In the PYG 02 cohort, officers are observed conditionally on their not having attrited after failing their first or second boards. In the PYG 03 cohort, officers are observed conditionally on their not having attrited after their first board.

Table 1 illustrates the truncation and censoring patterns of the data used in the thesis research. Table entries of "T" signify that data are truncated (not observed) at the indicated value of *Y*. Table entries of "C" signify that data are censored at the indicated value of *Y*.

Cohort	**Selected on first look (Y = 1)**	**Attrite after first look (Y = 2)**	**Selected on second look (Y = 3)**	**Attrite after second look (Y = 4)**	**Selected on third look (Y = 5)**	**Attrite after third look (Y = 6)**
PYG 02		T		T		
PYG 03		T		C	C	C
PYG 04		C	C	C	C	C

Table 1. Truncation and Censoring Patterns of Data.

4. Maximum Likelihood Estimation

To estimate the MHLR model parameters in the presence of both truncation and censoring, the entire model is fit to the data simultaneously using maximum likelihood. This is equivalent to maximizing the following log-likelihood function:

$$\mathcal{L}(\boldsymbol{\beta}_1, \boldsymbol{\beta}_2, \ldots, \boldsymbol{\beta}_{k-1}) = \mathcal{L}_C\,(\boldsymbol{\beta}_1, \boldsymbol{\beta}_2, \ldots, \boldsymbol{\beta}_{k-1}) - \mathcal{L}_\vartheta\,(\boldsymbol{\beta}_1, \boldsymbol{\beta}_2, \ldots, \boldsymbol{\beta}_{k-1})$$

$$\mathcal{L}_C\,(\boldsymbol{\beta}_1, \boldsymbol{\beta}_2, \ldots, \boldsymbol{\beta}_{k-1}) = \sum_{i=1}^{n} \log\left\{\sum\nolimits_{t \in C_i} p(t;\, \boldsymbol{x}_i(t))\right\}$$

$$\mathcal{L}_\vartheta\,(\boldsymbol{\beta}_1, \boldsymbol{\beta}_2, \ldots, \boldsymbol{\beta}_{k-1}) = \sum_{i=1}^{n} \log\left\{\sum\nolimits_{t \in \vartheta_i} p(t;\, \boldsymbol{x}_i(t))\right\}$$

The log-likelihood is expressed as a censoring contribution (C) minus a truncation contribution (ϑ). The set C_i consists of all values represented by the outcome for officer *i*. If this officer succeeded on the second board, for example, then $Y_i = 3$ and C_i consists of the single value 3. If this officer belonged to PYG 04 and failed to make his first board, then $Y_i > 1$ is right-censored and $C_i = \{2, 3, 4, 5, 6\}$. Because all censoring is right-censoring in our case, C_i consists either of a single number or as the set of all integers greater than or equal to a certain value.

The set ϑ_i consists of all outcomes that the officer was eligible to observe. If the officer belonged to the PYG 02 cohort, then $\vartheta_i = \{1, 3, 5, 6\}$; i.e., the outcomes $Y_i = 2$ and $Y_i = 4$ were truncated from this cohort. Similarly, officers in the PYG 03 cohort have $\vartheta_i = \{1, 3, 4, 5, 6\}$, because officers who will attrite after failing their second board ($Y_i = 4$) are included in the sample. Officers in the PYG 04 cohort are unaffected by truncation, and $\vartheta_i = \{1, 2, 3, 4, 5, 6\}$ for these officers.

The model parameters $\boldsymbol{\beta}_1, \boldsymbol{\beta}_2, \ldots, \boldsymbol{\beta}_{k-1}$ enter into the log-likelihood function through the probabilities $p(t;\, \boldsymbol{x}_i(t))$. Using the inversion relationship together with the logit model for the hazard function, these probabilities are expressed as follows:

$$p(t;\, \boldsymbol{x}_i(t)) = \begin{cases} \dfrac{\exp(\boldsymbol{x}_i'(t)\,\boldsymbol{\beta}_t)}{\prod_{j=1}^{t}\left[1 + \exp(\boldsymbol{x}_i'(j)\,\boldsymbol{\beta}_j)\right]}, & 1 \le t \le k-1 \\[2ex] \dfrac{1}{\prod_{j=1}^{k-1}\left[1 + \exp(\boldsymbol{x}_i'(j)\,\boldsymbol{\beta}_j)\right]}, & t = k \end{cases}$$

The likelihood is maximized by taking all first and second partial derivatives of $\mathcal{L}(\boldsymbol{\beta}_1, \boldsymbol{\beta}_2, \ldots, \boldsymbol{\beta}_{k-1})$ with respect to the parameters and using a Newton-Raphson

algorithm. The function `nlminb` in S-Plus was used to implement a Newton-Raphson algorithm on minus the log-likelihood because `nlminb` attempts to locate the minimum, as opposed to the maximum, of the user-supplied function. Upon successful convergence, the maximum likelihood estimates (MLEs) $\hat{\boldsymbol{\beta}}_1, \hat{\boldsymbol{\beta}}_2, \ldots, \hat{\boldsymbol{\beta}}_{k-1}$ were obtained. An estimated covariance matrix of the MLEs is obtained by inverting minus the Hessian of $\mathscr{L}(\boldsymbol{\beta}_1, \boldsymbol{\beta}_2, \ldots, \boldsymbol{\beta}_{k-1})$ evaluated at $\hat{\boldsymbol{\beta}}_1, \hat{\boldsymbol{\beta}}_2, \ldots, \hat{\boldsymbol{\beta}}_{k-1}$. Successful convergence ensures that the estimated covariance matrix is positive definite. Estimated standard errors of individual parameters are obtained as the square root of the corresponding diagonal element of the estimated covariance matrix. These and other concepts of maximum likelihood estimation are explained in Bickel and Doksum (2001).

5. Hypothesis Testing Under the Hazards Model

Under "regularity" conditions, maximum likelihood estimators are approximately unbiased and normally distributed in large samples (Bickel and Doksum, 2001). It can be verified that these conditions are satisfied by the hazards model. Based upon this property, individual parameter estimates are approximately normally distributed, centered on the true parameter values, with standard errors estimated as described above. Standardizing the estimated coefficients (dividing by their standard errors) gives a means of testing whether individual parameters are significantly different from zero. Standardized coefficients that exceed 1.96 in absolute value are significant at the $\alpha = .05$ test level.

To test whether sets of coefficients are equal to zero, a likelihood ratio test (LRT) is used (Montgomery, 2001). First, a "full model" is fit to the data that includes the parameters in question. Second, a "reduced model" is fit, containing all parameters of the full model except those that are being tested for equality to zero. Maximum likelihood is used to fit both the full and the reduced model. The LRT statistic is given by

$$\chi = 2\left[\mathscr{L}(\text{full model}) - \mathscr{L}(\text{reduced model})\right]$$

Under the null hypothesis that the parameters in question (those appearing in the full model but not in the reduced model) are equal to zero, the test statistic χ has

approximately a chi-square distribution with degrees of freedom equal to the number of parameters that are being tested. The null hypothesis is rejected at level α if χ exceeds the $1-\alpha$ quantile of the chi-square distribution with the corresponding degrees of freedom.

6. Data Used in Model Estimation

There are 616 total observations in the data set that was available for analysis. In 26 cases, data were missing in at least one key variable, and these observations were removed, leaving 590 usable observations for estimation under the MHLR model.

IV. ANALYSIS AND RESULTS

This chapter presents the results applying the MHLR model to the 2002-2004 SWO XO selection-board data. Nonparametric statistical methods are used to provide additional insights.

A. ASSUMPTIONS FOR DATA ANALYSIS

A basic assumption that underlies the analysis presented in this chapter is that the data can be regarded as equivalent to a random sample taken from a relevant population, in this case all officers who are subject to the SWO XO selection process. With the exception of officers who may have attrited from the process in the PYG 02 and PYG 03 cohorts, the data represent an exhaustive sample of the three cohort years that are studied. The assumption of randomness is that the selection process is stationary with respect to time, and that the cohorts included in the thesis research are representative of all officers who have been and will be subjected to this selection process.

Throughout the thesis research, it is assumed that each observation may be treated as an independent random sample from the population of interest, without sampling bias.

B. FITTING THE MULTISTAGE HAZARDS LOGISTIC REGRESSION (MHLR) MODEL

The base number of observations is 590, which is the number of officers from the PYG 02 through PYG 04 cohorts with complete data in all variables, (as defined in Chapter III). Further reductions in the data used for fitting the MHLR model must also be made for reasons that are discussed below. In order to fit the model a subset of the explanatory variables is then identified which contribute significantly to the estimation of probabilities related to outcomes of the XO selection process.

1. Data Excluded from the Analysis

To fit the MHLR model to the data, it is necessary to remove certain groups of data from the analysis. There groups are described below:

- Thirteen female SWOs were eligible for selection to XO in the PYG 02 through PYG 03 cohorts. These officers were excluded from model fitting for several reasons. First, it was desired not to assume that these officers were similar to male officers in the absence of evidence to that effect.

Second, there are not enough data from these thirteen officers to treat them separately in the MHLR model. And, as noted in Chapter II, Navy policy specifically states that board members must ensure candidates are not disadvantaged due to gender. Therefore, these thirteen female SWOs are not included in the model. Six of the thirteen female SWOs (46 percent) were selected for XO, compared with 258 of the 577 male SWOs (45 percent).

- All officers receive a promotion recommendation on their FITREP. Any rating of "significant problems" or "progressing" is considered to be an adverse report. Receiving either of these marks significantly reduces an officer's chance of selection. Sixteen officers received an adverse report and none was selected. Due to this strongly negative effect, these 16 officers are not included in the analysis.

- Command at sea at the O3 pay grade is considered to be a significant achievement and is a career milestone. Twenty-two officers had command at sea at the O3 pay grade, and all of them were selected for XO. Due to this strongly positive effect, these 22 officers are not included in the analysis.

After removing these three classes of officers, 540 officers remain in the data that are used in the analysis.

2. Choice of Explanatory Variables

The following table defines the explanatory variables used in the MHLR model. Not all variables were used in every analysis. The models considered in this thesis are as follows:

- The **full model** contains 34 explanatory variables extracted from the OAIS and EMPRS data. These explanatory variables are used over five regressions in the MHLR model.

- Four **reduced models**, each containing a subset of the 34 explanatory variables in the full model, are defined. The reduced models are used to test the significance of explanatory variables in estimating probabilities related to the XO selection process.

Detailed descriptions of the models considered in this thesis are given in the appendix.

Variable	**Description**
DC	Whether an officer has completed a tour in Washington DC or the Bureau of Naval Personnel (1 = Yes, 0 = No).
MA	Whether an officer has completed a Master's degree (1 = Yes, 0 = No).
JPME	Whether an officer has completed Joint Professional Military Education Phase I (1 = Yes, 0 = No).
NUKE	Whether an officer is nuclear trained (1 = Yes, 0 = No).
EAST	Whether an officer has completed a DH tour in a billet on the East Coast (1 = Yes, 0 = No).
WEST	Whether an officer has completed a DH tour in a billet on the West Coast (1 = Yes, 0 = No).
LEFT1, LEFT2, LEFT3	Whether an officer has promotion recommendation that decreased over time on his FITREPs (1 = Yes, 0 = No).
O3SCORE	A score based on FITREP ratings received at the O3 pay grade. Higher scores imply that the officer received higher-than-average ratings than peers at this pay grade.
EARLY.ROLLER	Whether an officer was an early roller (go directly from DIVO tours to DH tours) (1 = Yes, 0 = No).
PRIOR	Whether an officer was prior enlisted (1 = Yes, 0 = No).
3^{RD} DH AFLT	Whether an officer completed three department head tours afloat (1 = Yes, 0 = No).

Table 2. Explanatory Variables Used in the Models.

The following gives a more detailed explanation of how the O3SCORE score is calculated:

Step 1 Determine cutoff date of FITREPs. The cutoff date is 31 March in the year than a SWO is first reviewed by a XO selection board. O3SCORE uses all FITREP information up to the cutoff date for the time that the SWO was at the O3 pay grade.

Step 2 For each FITREP rating at the O3 pay grade up to the cutoff date, divide by the average FITREP rating issued by the same reporting senior officer. Exclude any FITREP for which the officer received a rating of "NOB" (Not Observed).

Step 3 Take the minimum of the ratios described in Step 2. If there was only one reporting senior officer for the SWO at the O3 pay grade, only that ratio is used.

An O3SCORE equal to one implies that the candidate is at the average rating for a senior reporting officer at the O3 pay grade. Values less than one suggest lower-than-average ratings, and values greater than one suggest higher-than-average ratings.

3. Software for Model Fitting

The data were analyzed using software that was written in the S-Plus® 7.0.0 (Insightful Corp.) statistical programming language. S-Plus functions were written for the likelihood function of the MHLR model under censoring and truncation, and for the first and second derivatives of the likelihood function. The `nlminb` function in S-Plus used these functions to maximize the likelihood, which in turn provided maximum likelihood estimates of the MHLR model parameters. The `nlminb` function uses a Newton-Raphson algorithm to find the maximum of the likelihood function. Estimated standard errors of the model parameter estimates were obtained from the second derivative matrix (Hessian) that was output from `nlminb`.

Microsoft Excel 2003® (Microsoft Corp.) was also used for the creation of graphs in the thesis.

4. Testing for the Significance of Truncation

As explained in Chapter III, truncation occurs because officers who attrited from the XO selection process between boards are not observed. The MHLR model includes probabilities for attrition after the first board ($Y = 2$) and after the second board ($Y = 4$). Including these probabilities in the model may present numerical problems, due to the inability of the model to distinguish the occurrence of truncation from the data in the presence of truncation and censoring. This would result in the model attempting to assign probabilities of zero to these events, which can happen only if the corresponding

parameters approach negative infinity. Although these probabilities cannot be equal to zero as a matter of principle, the model may not be able to detect a signal to that effect from the data. In essence, setting these probabilities equal to zero in the model is the same as treating the sample data as if truncation were not present. The issue is whether ignoring truncation has a significant effect on model estimation.

In testing for the significance of truncation, a **full model** and a **full model without truncation** are defined. The full model has 34 parameters distributed over five regressions. Table 3 lists the explanatory variables appearing in the full model. The full model without truncation (which assigns probabilities of zero to the two attrition outcomes) has 32 parameters distributed over three regressions. Both models are fit to the data, and a likelihood ratio test (LRT) (Montgomery, 2001) is used to ascertain whether the full model (which includes attrition) is significantly better than the full model without truncation. Failure to reject the null hypothesis would suggest that there is no evidence that ignoring attrition reduces the quality of estimation.

Regression 1	**Regression 2**	**Regression 3**	**Regression 4**	**Regression 5**
1. CONST	13. CONST*	14. CONST	24. CONST*	25. CONST
2. DC		15. MA		26. MA
3. MA		16. JPME		27. JPME
4. JPME		17. NUKE		28. NUKE
5. NUKE		18. EAST		29. EAST
6. EAST		19. WEST		30. WEST
7. WEST		20. LEFT2		31. LEFT3
8. LEFT1		21. O3SCORE		32. O3SCORE
9. O3SCORE		22. PRIOR		33. PRIOR
10. EARLY.ROLLER		23. 3^{RD} DH AFLT		34. 3^{RD} DH AFLT
11. PRIOR				
12. 3^{RD} DH AFLT				

Table 3. Explanatory Variables Used in Full Model.
The full model without truncation contains the same explanatory variables shown in the table, with the exception of Regression 2 and Regression 4 which are absent from the model without truncation.

Parameter estimates obtained from the full model and full model without truncation are presented in the Appendix. The p - value of the LRT is approximately equal to .746 and the null hypothesis cannot be rejected at the $\alpha = .05$ test level.The null hypothesis that the probabilities of falling into categories $Y = 2$ and $Y = 4$ are both equal to 0 is not rejected because there is insufficient evidence from the data to the contrary. Further estimation, however, is based on the full MHLR model.

C. TESTING FOR SIGNIFICANCE OF EXPLANATORY VARIABLES

A series of reduced MHLR models are considered to test the significance of explanatory variables of interest. These models are compared to the full model defined above and LRTs are conducted to determine whether the explanatory variables in question are statistically significant. Four reduced models are considered. These model-fitting exercises suggest that, at an officer's first review, DC, MA, and O3SCORE are significant factors in determining his probability of success. Given that an officer was not selected in his first review, his probability of success at the second review is most strongly influenced by EAST, WEST, and O3SCORE. Finally, given that an officer was not selected in his first or second review, his probability of success at the third (and final) review is most strongly influenced by NUKE and O3SCORE.

Four reduced models were built that tested the significance of certain explanatory variables. The results of each reduced model are presented in the Appendix. Table 4 summarizes the results of these tests.

Model	**Parameters**	**Log-likelihood**	**Deviance**	**Df**	**p - value**
Full	34	-429.3729			
Reduced without DC, MA, and JPME	27	-444.5796	30.053	7	0.000
Reduced without DC	33	-437.0581	15.370	1	0.000
Reduced without MA	33	-434.4084	10.071	1	0.018
Reduced without JPME	31	-432.9797	7.2136	1	0.065

Table 4. Result of Test of Significance of Explanatory Variables Deviance is defined as two times the difference of the log-likelihood in both the full model and reduced model (Montgomery, 2001).

- Reduced Model without DC, MA, and JPME Variables

This reduced model includes 27 parameters. It includes all of the explanatory variables from the full model except DC, MA, and JPME. These variables are all shore-duty-related variables that are assumed to be not achievable while on sea duty.

The results of this model indicate that for all three reviews an officer can have, the O3 score is the single-most-important variable. This variable is an extremely positive variable toward the regressions, and in regressions one, three, and five (regressions which represent a selection board), the p - value is 0.

This reduced model has a log-likelihood of -444.5796. The LRT of this model with respect to the full model defined earlier is equivalent to testing the following hypotheses:

$$H_0 : \beta_2 = \beta_3 = \beta_4 = \beta_{15} = \beta_{16} = \beta_{26} = \beta_{27} = 0$$

$$H_1 : \text{ not } H_0$$

The null hypothesis is equivalent to the statement that none of the seven explanatory variables in the full model involving DC, MA, and JPME affect an officer's probability of selection to XO. The alternative hypothesis is the opposite statement, namely that at least one of these seven variables does affect the probability of selection. Assuming a model deviance chi-squared distribution with seven degrees of freedom, the p - value is approximately 0. Therefore, the null hypothesis can be rejected at the $\alpha = .05$ level which suggests that DC, MA, and JPME significantly contribute to the MHLR model.

- Reduced Model without DC Variable

This reduced model includes 33 parameters. It includes all of the explanatory variables from the full model except DC. The results of this model indicate that for all three reviews an officer can have, the O3 score is the single-most-important-variable. This variable is an extremely positive variable toward the regressions, and in regressions one, three, and five (regressions which represent a selection board), the p - value is approximately 0.

This reduced model has a log-likelihood of -437.0581. Assuming a chi-squared distribution with one df, the p- value is approximately 0. The null hypothesis can be rejected at the $\alpha = .05$ level, and it shows that DC is significant to the model.

- Reduced Model without MA Variable

This reduced model includes 31 parameters. It includes all of the explanatory variables from the full model except MA. The results of this model indicate that for all three reviews an officer can have, the O3 score is the single-most-important-variable. This variable is an extremely positive variable toward the regressions, and in regressions one, three, and five (regressions which represent a selection board), the p- value is approximately 0.

This reduced model has a log-likelihood of -434.4084. Assuming a chi-squared distribution with three df, the p- value is approximately 0.018. The null hypothesis can be rejected at the $\alpha = .05$ level, and it shows that MA is significant to the model.

- Reduced Model without JPME Variable

This reduced model includes 31 parameters. It includes all of the explanatory variables from the full model excep: JPME. The results of this model indicate that for all three reviews an officer can have, the O3 score is the single-most-important-variable. This variable is an extremely positive variable toward the regressions, and in regressions one, three, and five (regressions which represent a selection board), the p- value is approximately 0.

This reduced model has a log-likelihood of -432.9797. Assuming a chi-squared distribution with three df, the p- value is approximately 0.065. Although the null hypothesis cannot be rejected at the $\alpha = .05$ level, it is rejected at the $\alpha = .10$ level, which suggests that JPME is a marginally important factor in the model.

C. Probabilities of selection

The MHLR model can be used to predict whether an officer will be selected for XO. An officer is predicted to have an outcome (value of *Y*) that has the highest probability among the six possible outcomes. For example, if the highest probability is $Y = 1$, a SWO is predicted to be selected on his first look. For officers whose data are

used in the thesis research, it is possible to compare these predictions to actual outcomes, provided that their outcomes are not censored. They include all officers from PYG 02, officers from PYG 03 who were selected on the first or second review, and officers from PYG 04 who were selected on the first review. A total of 309 officers belong to these groups. Figure 3 shows boxplots that describe the distributions of predicted probabilities for each of the actual outcomes among the 309 officers used in this analysis.

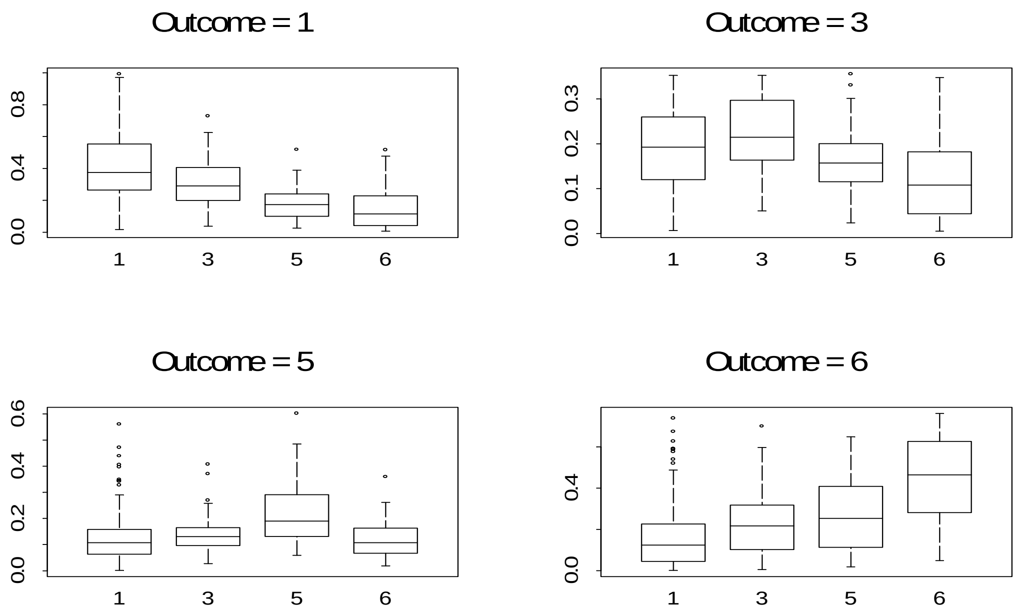

Figure 3. For Each Actual Outcome, a Box Plot Graphs the Predicted Probability Versus Actual Outcomes for Each Predicted Outcome State.

A box plot can be read as follows. The lowest line in each column is the minimum value, the lower line of the box is the 25th percentile, the middle line in the box is the median (50th percentile), the upper line in the box is the 75th percentile, and the highest line is the maximum value. For example, among SWOs who were selected in their first review (Y = 1), the estimated probabilities of selection in the first review vary about a median of approximately .40. Moreover, these probabilities are higher than for any of the other outcomes. A similar pattern also holds for officers who were selected in the second and third reviews, and officers who were not selected. Generally, officers who were

selected in one of the three reviews had low probabilities of not being selected, and officers who were not selected had not being selected as their most likely outcome.

The following table shows the prediction accuracy of the MHLR model. All selection outcomes ($Y = 1, 3$, or 5) are combined and contrasted with the non-selection outcome ($Y = 6$), again using the 309 officers described above. An officer is predicted to be selected if the estimated probability of selection exceeds the estimated probability of non-selection. Similarly, an officer is predicted not to be selected if this outcome has a higher estimated probability than that of being selected. The model correctly classifies approximately 76 percent of officers who were actually selected, and 79 percent of officers who were not selected.

Description	**Selection**	**Total Observations**	**Correct Classification**
Predicted board selection	187	247	75.7%
Predicted board non-selection	13	62	79.0%

Table 5. Accuracy of the Full Model.

D. MANTEL-HAENSZEL TEST

1. Methodology

A nonparametric approach was taken to explore whether having certain variables affects selection. Due to truncation and right censoring, only an officer's first board review can be analyzed. A series of upper-tailed Mantel-Haenszel tests (Conover, 1999) were conducted to assess dependence among variables conditional on the year group of an officer.

The Mantel-Haenszel test is used for testing independence of two dichotomous variables conditional on a third (discrete) variable. The data are cross-classified according to the three variables, resulting in a series of *k* two-by-two contingency tables, where *k* is the number of levels of the conditioning variable. The i^{th} level of the conditioning variable is represented in Table 6:

	Column 1	**Column 2**	
Row 1	x_i	$r_i - x_i$	r_i
Row 2	$c_i - x_i$	$N_i - r_i - c_i + x_i$	$N_i - r_i$

c_i	$N_i - c_i$	N_i

The total number of observations in the i^{th} table is N_i. Cells in the table show counts in the given row and column. The column total in the i^{th} table is c_i. The row total of the i^{th} table is r_i.

Table 6. Representation of Contingency Tables for Use in the Mantel-Haenszel Test. (Conover, 1999)

Each observation is classified into exactly one cell for each contingency table. Further, the row and column totals are fixed, not random. The test statistic is shown as follows:

$$T = \frac{\sum x_i - \sum (r_i c_i)/N_i}{\sqrt{\sum r_i c_i (N_i - r_i)(N_i - c_i)/N_i^3}}$$

The distribution of T is approximately standard normal when the null hypothesis of conditional independence between rows and columns is true. Specifically, let p_{1i} be the probability of an observation in Row 1 being classified into Column1, in the i^{th} contingency table, and let p_{2i} be the probability of an observation in Row 2 being classified into Column1. For an upper-tail test, the following hypothesis is tested:

$H_0 : p_{1i} \le p_{2i}$, for all $i = 1, \dots, k$

$H_1 : p_{1i} \ge p_{2i}$ for all i, and $p_{1j} > p_{2j}$ for at least one j.

The null hypothesis is rejected at level α if T is greater than the $1-\alpha$ quantile of the standard normal distribution. Equivalently, the null hypothesis is rejected if the p - value (i.e., the probability of a standard normal random variable being greater than the observed value of T) is less than α.

In the following analyses, "Row" refers to any of several dichotomous explanatory variables including MA, JPME, DC, EAST, and WEST; "Column" refers to the outcome of being selected or not selected at the first review. The conditioning

variable is the year-group of an officer, which takes on the values PYG 02, PYG 03, or PYG 04 (k = 3). A total of 540 officers (those used in fitting the MHLR model) are used in the Mantel-Haenszel tests.

2. Mantel-Haenszel Test Results

- MA versus Selection

The Mantel-Haensel test statistic is T = .2924 with a p - value of .5887. This p - value suggests that there is insufficient evidence to reject the null hypothesis at a significance level of $\alpha = .05$.

- DC versus Selection

The Mantel-Haenszel Test produced a value of 19.8569 with a p - value of 0. This p - value suggests strong evidence against the null hypothesis at a significance level of $\alpha = .05$.

- JPME versus Selection

The Mantel-Haenszel Test produced a value of 5.7421 with a p - value of .0166. This p - value suggests strong evidence against the null hypothesis at a significance level of $\alpha = .05$.

- EAST versus Selection

The Mantel-Haenszel Test produced a value of .3085 with a p - value of .5786. This p - value suggests that there is no evidence from the known data to reject the null hypothesis at a significance level of $\alpha = .05$.

- WEST versus Selection

The Mantel-Haenszel Test produced a value of .3044 with a p - value of .5811. This p - value suggests that there is no evidence from the available data to reject the null hypothesis at a significance level of $\alpha = .05$.

Table 7 summarizes the results of the Mantel-Haenszel tests:

Variable	df	Value	p - value	Conclusion
MA	1	0.2924	0.589	Do Not Reject Null Hypothesis
DC	1	19.8569	0.000	Reject Null Hypothesis
JPME	1	5.7421	0.0166	Reject Null Hypothesis
EAST	1	0.3085	0.5786	Do Not Reject Null Hypothesis
WEST	1	0.3044	0.5811	Do Not Reject Null Hypothesis

Table 7. Results of Upper-Tailed Mantel-Haenszel Tests at the $\alpha = .05$ Test Level.

E. CONDITIONING ON O3 SCORE

1. Methodology

Results of the Mantel-Haenszel suggest that having a Master's Degree, having completed an East Coast DH tour, or having completed a West Coast DH tour does not affect a candidate's probability of selection to XO, but having completed a Washington DC or BUPERS tour and having completed JPME has a positive effect on selection. Based on the results of the Manel-Haenszel test and the results of the MHLR model, the O3SCORE remains the most important factor contributing to selection or non-selection to XO.

To explore the effects of dichotomous variables conditional on O3SCORE, the results of each officer's first review are cross-tabulated. The first review is used because it is unaffected by censoring in all three cohort groups. The conditioning event is that O3SCORE is less than or equal to *s*, where *s* varies between .88 and 1.14. Table 8 is an example of the table used.

	PYG		
	Selected	**Not Selected**	**Total Percent Selected**
Officer with Trait of Concern	x	y	$x/(x+y)$
Officer without Trait of Concern	a	b	$a/(a+b)$

Table 8. Table Used to Determine the Proportion Selected Conditioned Upon the O3SCORE.

The variable x represents the total number of officers selected with the trait of concern. The variable y represents the total number of officers not selected with the trait of concern. The variable a represents the total number of officers selected without the trait of concern. The variable b represents the total number of officers not selected without the trait of concern. The total percent selected column is derived by dividing the number of officers selected by the sum of the number selected and not selected in each group.

This test is cumulative in the sense that the O3SCORE is variable and as the O3SCORE gets larger, a larger number of officers are included. Conditioning on O3SCORE less than or equal to s in the range [.88, 1.14] was performed in increments of .02.

2. Results of Conditioning on O3SCORE

- Washington DC or BUPERS Tour versus Selection

Conditioning on O3SCORE as described above, having completed a tour in Washington DC or BUPERS improves the chances of selection to XO. This result is consistent with the findings of the MHLR model that having completed a Washington DC or BUPERS tour is a positive contributor to the MHLR model. It must be noted that an unfavorable O3SCORE is a difficult obstacle for a SWO to overcome. Figures 4 through 6 show the proportion selected for XO broken down by cohort.

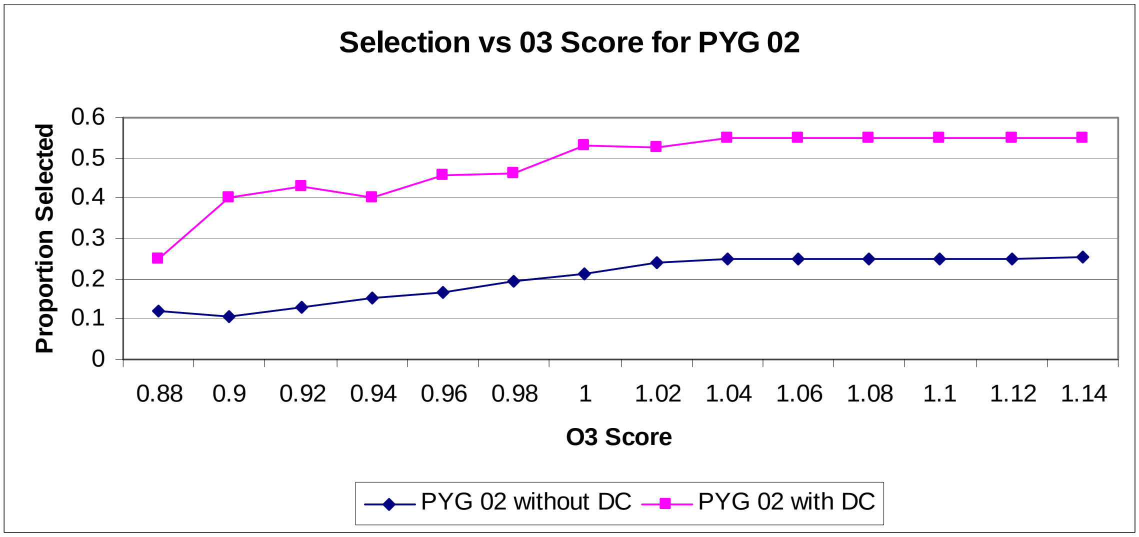

Figure 4. **The Proportion Selected to XO Versus O3SCORE of the Officer for the PYG 02 Cohort Group and the DC Variable.**

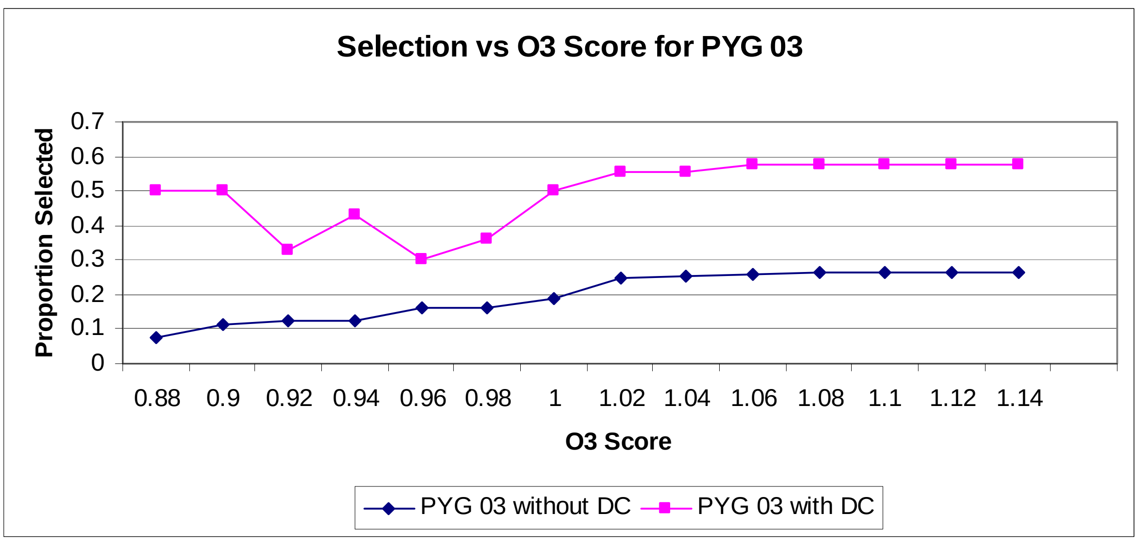

Figure 5. **The Proportion Selected to XO Versus O3SCORE of the Officer for the PYG 03 Cohort Group and the DC Variable.**

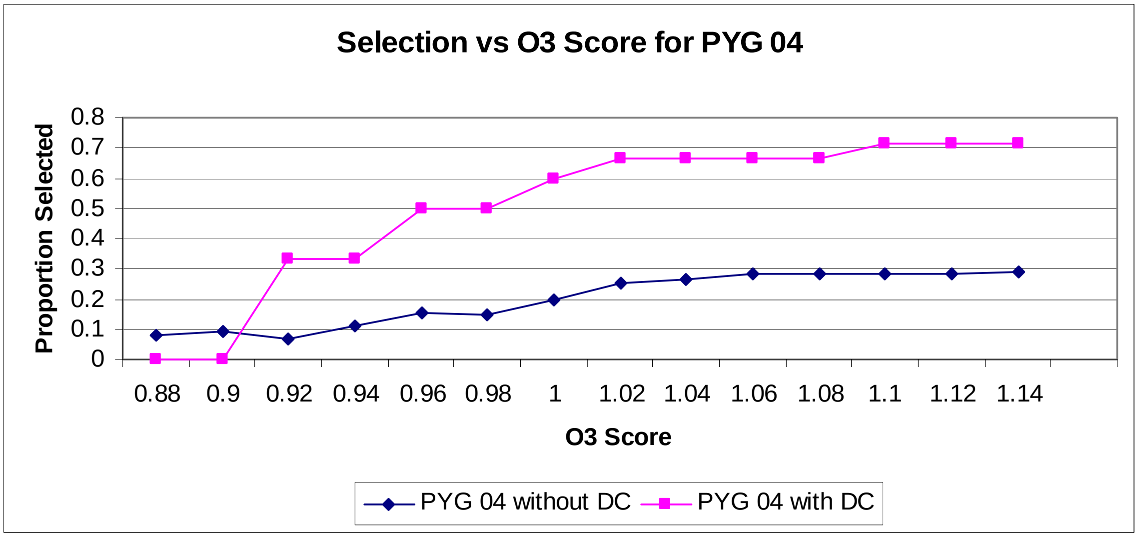

Figure 6. The Proportion Selected to XO Versus the O3SCORE of the Officer for the PYG 04 Cohort Group and the DC Variable.

Figures 4 through 6 reveal useful insights into the importance of O3SCORE to an officer's chance of selection. An officer with a low O3SCORE has very little chance of being selected without having completed a Washington DC or BUPERS tour. Completed such a tour significantly increases his chance of selection regardless of O3SCORE.

- The Effect of a Master's Degree Conditioned on O3SCORE

Conditioning on the O3SCORE, having completed a Master's Degree does not improve the chance of selection to XO. This result is consistent with the findings of the MHLR model that having a Master's Degree does not contribute to selection. Figures 7 through 9 show the proportion selected by PYG conditioning of O3SCORE.

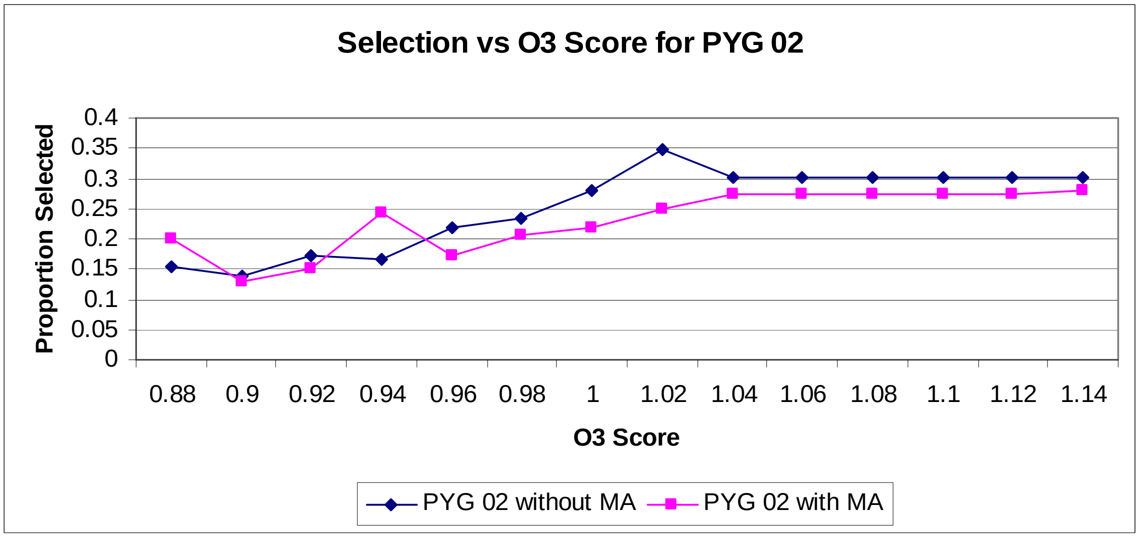

Figure 7. The Proportion Selected to XO Versus O3SCORE of the Officer for the PYG 02 Cohort Group and the MA Variable.

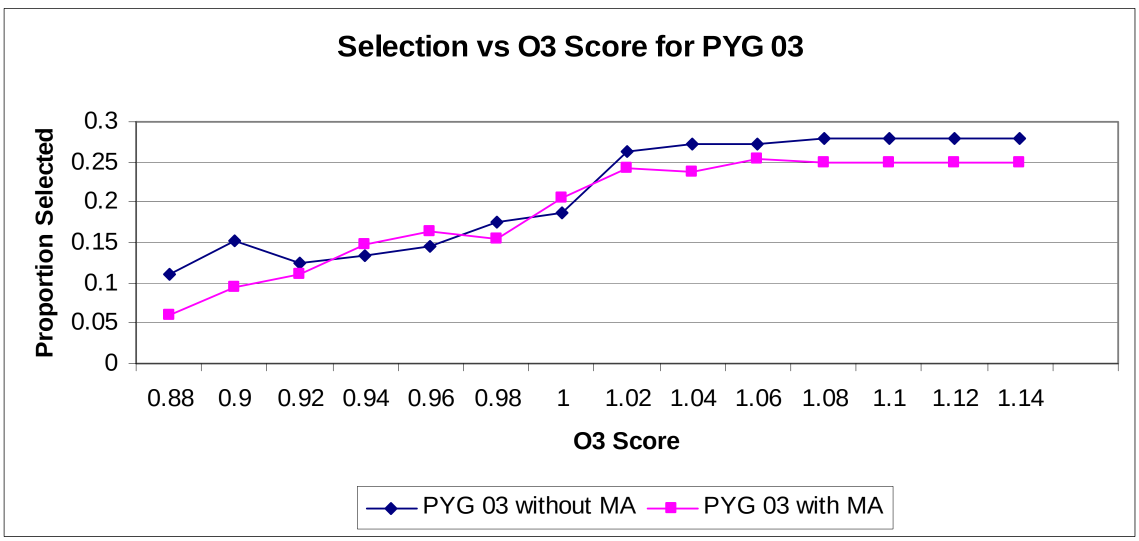

Figure 8. The Proportion Selected to XO Versus O3SCORE of the Officer for the PYG 03 Cohort Group and the MA Variable.

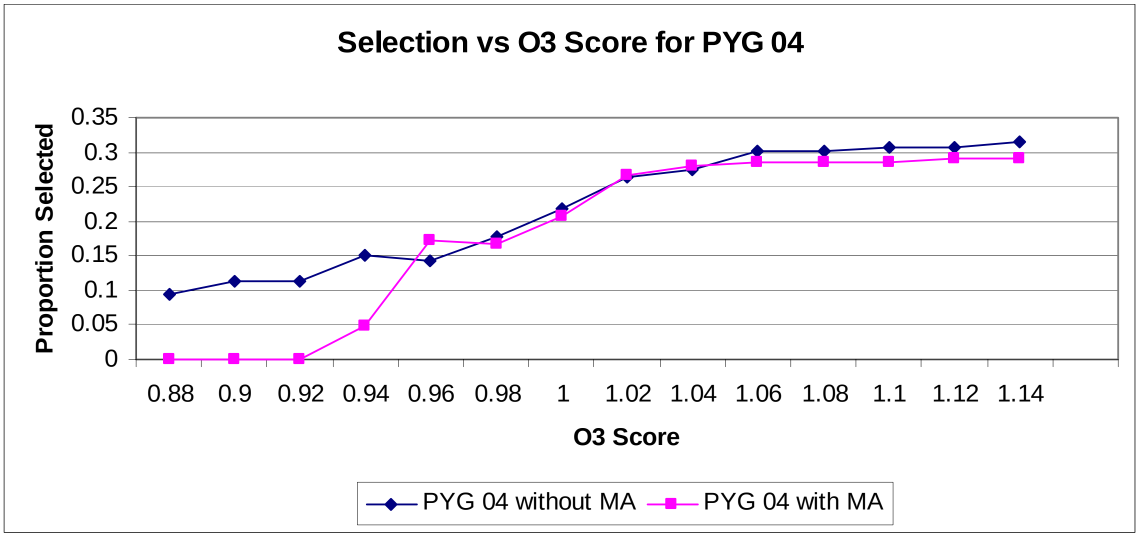

Figure 9. The Proportion Selected to XO Versus the O3SCORE of the Officer for the PYG 04 Cohort Group and the MA Variable.

Figured 7 through 9 demonstrate how having a Master's Degree is not that influential in determining whether an officer will be selected for XO. In all three cohort groups, of the officers with a higher O3SCORE, a higher proportion of officers without Master's Degrees were selected than those with Master's Degrees. This trend leads to the conclusion that having a Master's Degree does not increase the chances of selection and that the O3SCORE is more important between these two variables.

- The Effect of JPME Conditioned on O3SCORE

Conditioning on the O3SCORE, having completed JPME does improve the chance of selection to XO. This result is consistent with the findings of the MHLR model that having completed JPME is a positive contributor to the MHLR model. Figures 10 through 12show the proportion selected by PYG.

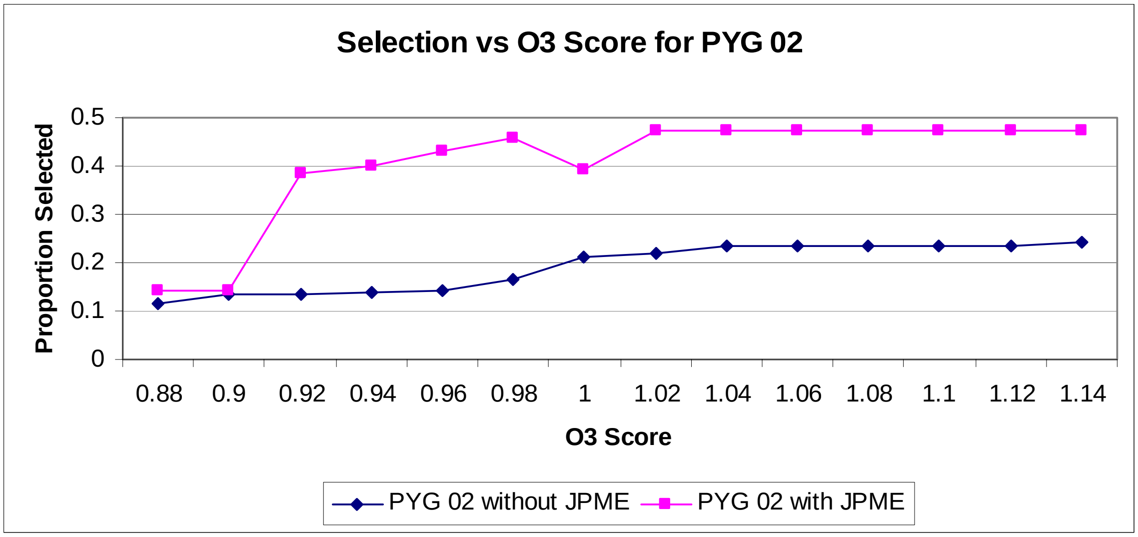

Figure 10. The Proportion Selected to XO Versus O3SCORE of the Officer for the PYG 02 Cohort Group and the JPME Variable.

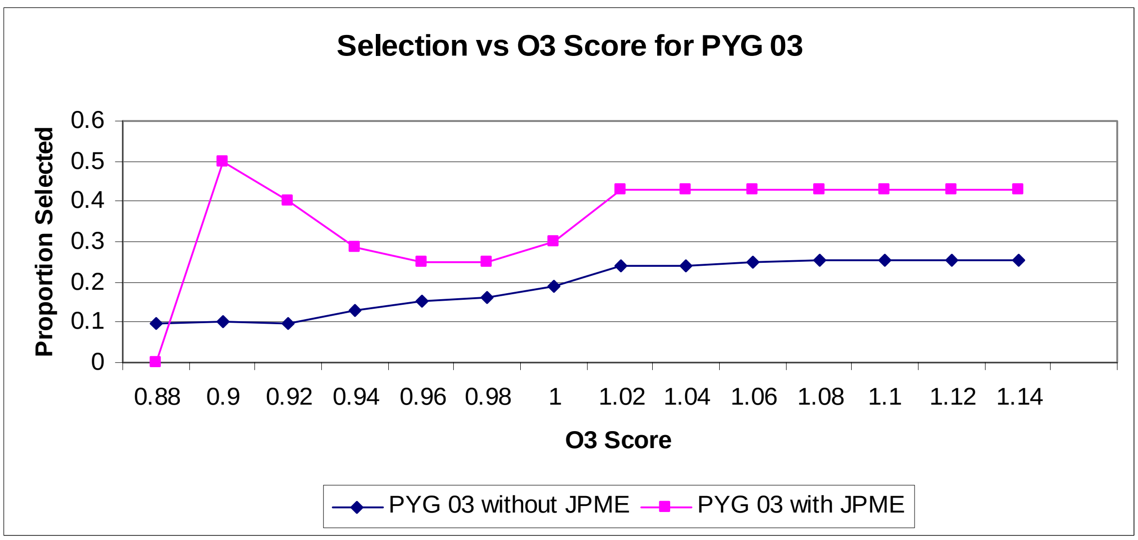

Figure 11. The Proportion Selected to XO Versus O3SCORE of the Officer for the PYG 03 Cohort Group and the JPME Variable.

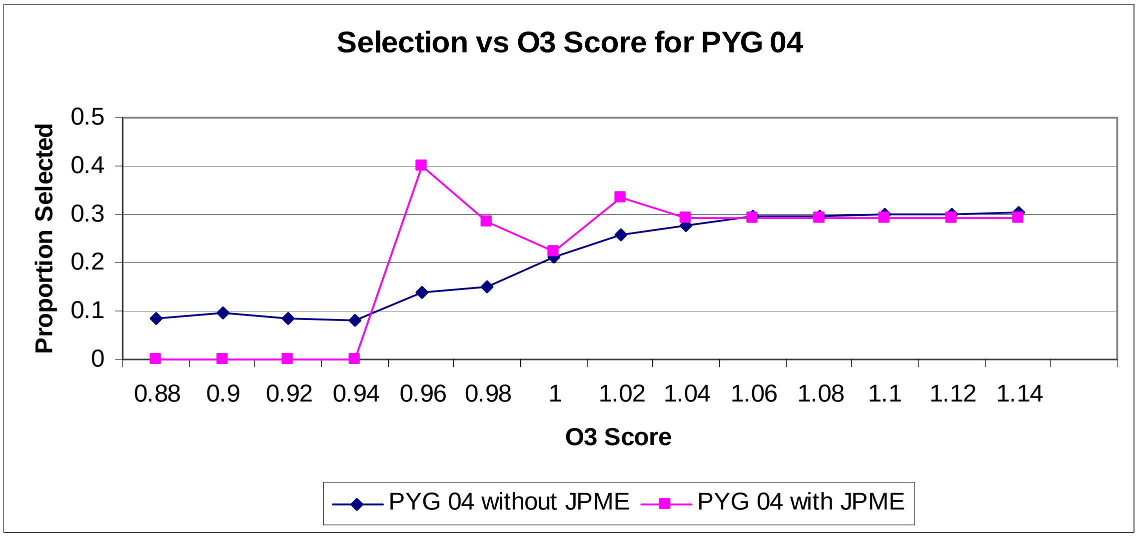

Figure 12. The Proportion Selected to XO Versus O3SCORE of the Officer for the PYG 04 Cohort Group and the JPME Variable.

The above graphs suggest that having completed JPME is a contributing factor to selection. In PYG 02 and PYG 03, having completed JPME significantly increases the probability of selection regardless of O3SCORE.

V. CONCLUSIONS

This thesis attempts to answer four research questions. These research questions allow for quantification of the selection board process. They allow for an officer to understand what his chances are for selection to XO and to be able to best manage his career. These questions and their resulting answers appear below.

A. RESEARCH QUESTIONS

- **How Important is Performance at Sea to Being Selected to Executive Officer?**

The results show that both shore and sea duty variables are important. However, an officer's DH FITREP scores have the largest influence on selection to XO. Additionally, SWOs who serve in command at the O3 pay grade select at a higher rate than do other officers. These officers are given responsibility early in their career and their performance during this challenging sea duty job sets them apart from their peers.

- **What is the Probability that a Surface Warfare Officer Will be Selected for Executive Officer by the First Selection Board, the Second Selection Board, the Third Selection Board, or that he will not be Selected?**

The MHLR model described in this thesis is able to predict whether an officer will or will not be selected for XO. This model can be applied to past, present, or future data sets assuming the selection board process stays constant. For the PYG 02, 03, and 04 cohort groups, an officer that is predicted to select for XO will select 75.7 percent of the time and an officer that is predicted to fail to select for XO will fail to select 79 percent of the time.

- **Which Factors in a Surface Warfare Officer's Career Profile Improve his Chances for Selection to Executive Officer?**

It has been established through this thesis that the single most important variable affecting selection for XO is an officer's DH FITREP scores. In other words, superior performance at sea as a DH (greater than 1.0 if using the model in this thesis) has the largest influence on an officer's potential selection to XO. Variables such as having

completed a tour in Washington DC or BUPERS or having completed a Master's Degree are significant, but sustained superior performance at sea (DH FITREP scores) carries the most weight.

- **Which Factors in a Surface Warfare Officer's Career Profile Reduce his Chances for Selection to Executive Officer?**

Fitness Report scores are key to selection to XO. An officer with low FITREP scores (below 1.0 if using the model in this thesis) will reduce his chances for selection to XO. It is difficult to recover from low FITREP scores regardless of any other jobs or education an officer has completed. Every officer who was rated below "promotable" on a FITREP failed to select for XO.

B. FUTURE RESEARCH

There are many additional research opportunities that can evolve from this thesis. First and foremost is data reliability. Due to unavailability of data, there is truncation. If the information of all the officers at the beginning of the first board review were available, the estimates of the model would be significantly improved. In other words, reworking the model without truncation would improve the estimates of the model. Additionally, if data were available for other boards, the amount of right censoring would decrease which again would improve the estimates of the model.

The results of this research indicate that an officer only is given one chance to perform. If an officer's performance causes him to receive a mark below "Promotable" at anytime after reaching the O3 pay grade, it will cause him to never be competitive for selection again. An interesting research topic would be to study these officers to see if they are still suitable for XO even if they made a mistake in the past that caused them to receive a mark below "Promotable."

The MHLR model is programmed and implemented in the S-Plus® 7.0.0 (Insightful Corp.) statistical programming language. It would be desirable to have this model made available in other software platforms that the SWO community could use on a regular basis. Using predicted probabilities obtained from the MHLR model, the SWO community could optimize the assignment of mid-grade officers.

APPENDIX

Model	Parameters	Log-likelihood	Deviance	Df	*p* - value
Full	34	-429.3729			
Full Model without Truncation	27	-429.6658	.5858	2	0.746

Table 9. Estimates from the Full Model and Full Model without Truncation.

Regression	Variable Name	Coefficient	Standard Error	Std Coefficient	*p* - value
1	CONST	-12.85	1.99	-6.46	0.00
1	DC	1.40	0.36	3.88	0.00
1	MA	-0.63	0.23	-2.76	0.01
1	JPME	0.73	0.30	2.42	0.02
1	NUKE	0.18	0.34	0.53	0.59
1	EAST	-0.44	0.34	-1.30	0.19
1	WEST	-0.36	0.33	-1.09	0.28
1	LEFT1	-0.16	0.41	-0.40	0.69
1	O3SCORE	13.23	2.03	6.53	0.00
1	EARLY.ROLLER	2.10	0.72	2.91	0.00
1	PRIOR	-0.38	0.23	-1.67	0.10
1	3RD DH AFLT	-0.14	0.67	-0.20	0.84
2	CONST	-2.47	3.17	-0.78	0.44
3	CONST	-11.56	2.80	-4.13	0.00
3	MA	0.05	0.34	0.14	0.89
3	JPME	0.57	0.49	1.16	0.25
3	NUKE	-0.59	0.64	-0.91	0.36
3	EAST	-0.95	0.55	-1.73	0.08
3	WEST	-1.15	0.51	-2.26	0.02
3	LEFT2	-0.51	0.56	-0.91	0.36
3	O3SCORE	12.76	2.95	4.32	0.00
3	PRIOR	-0.43	0.35	-1.22	0.22
3	3RD DH AFLT	-0.17	0.71	-0.24	0.81
4	CONST	-1.88	1.94	-0.97	0.33
5	CONST	-11.66	4.09	-2.85	0.00
5	MA	0.82	0.55	1.48	0.14
5	JPME	0.50	0.79	0.63	0.53
5	NUKE	2.85	1.21	2.35	0.02
5	EAST	0.07	0.73	0.10	0.92
5	WEST	0.17	0.64	0.26	0.80
5	LEFT3	-0.41	0.71	-0.58	0.56
5	O3SCORE	10.97	4.40	2.50	0.01
5	PRIOR	0.39	0.57	0.68	0.49
5	3RD DH AFLT	0.63	1.06	0.59	0.56

Table 10. Full Model Used in Testing Significance of Explanatory Variables.

Regression	Variable Name	Coefficient	Standard Error	Standard Coefficient	*p* - value
1	CONST	-12.05	1.89	-6.38	0.00
1	NUKE	0.09	0.33	0.28	0.78
1	EAST	-0.42	0.33	-1.29	0.20
1	WEST	-0.33	0.32	-1.04	0.30
1	LEFT1	-0.17	0.41	-0.42	0.67
1	O3SCORE	12.19	1.89	6.44	0.00
1	EARLY.ROLLER	2.27	0.70	3.26	0.00
1	PRIOR	-0.38	0.22	-1.71	0.09
1	3RD DH AFLT	-0.33	0.66	-0.50	0.62
2	CONST	-1.47	1.28	-1.15	0.25
3	CONST	-11.67	2.75	-4.24	0.00
3	NUKE	-0.61	0.64	-0.96	0.33
3	EAST	-0.94	0.55	-1.72	0.08
3	WEST	-1.16	0.51	-2.29	0.02
3	LEFT2	-0.57	0.56	-1.02	0.31
3	O3SCORE	12.97	2.86	4.54	0.00
3	PRIOR	-0.49	0.35	-1.41	0.16
3	3RD DH AFLT	-0.10	0.71	-0.15	0.88
4	CONST	-1.45	1.29	-1.12	0.26
5	CONST	-12.48	4.17	-2.99	0.00
5	NUKE	2.70	1.16	2.33	0.02
5	EAST	0.13	0.70	0.18	0.85
5	WEST	0.17	0.61	0.29	0.77
5	LEFT3	-0.31	0.70	-0.44	0.66
5	O3SCORE	12.46	4.39	2.84	0.00
5	PRIOR	0.29	0.55	0.52	0.60
5	3RD DH AFLT	0.76	1.04	0.73	0.46

Table 11. Reduced Model with no MA, JPME, and DC Used in Testing Significance of Explanatory Variables.

Regression	Variable Name	Coefficient	Standard Error	Standard Coefficient	*p* - value
1	CONST	-13.42	1.93	-6.95	0.00
1	MA	-0.62	0.22	-2.88	0.00
1	JPME	0.81	0.28	2.88	0.00
1	NUKE	0.00	0.33	0.00	1.00
1	EAST	-0.28	0.31	-0.91	0.36
1	WEST	-0.23	0.30	-0.76	0.45
1	LEFT1	-0.22	0.39	-0.56	0.58
1	O3SCORE	13.76	1.96	7.00	0.00
1	EARLY.ROLLER	2.13	0.71	3.00	0.00
1	PRIOR	-0.38	0.22	-1.74	0.08
1	3RD DH AFLT	-0.47	0.67	-0.70	0.49
2	CONST	-1.02	0.89	-1.14	0.25
3	CONST	-11.93	2.79	-4.28	0.00
3	MA	0.01	0.33	0.02	0.98
3	JPME	0.55	0.49	1.12	0.26
3	NUKE	-0.64	0.64	-1.00	0.32
3	EAST	-0.95	0.55	-1.73	0.08
3	WEST	-1.23	0.51	-2.42	0.02
3	LEFT2	-0.37	0.53	-0.70	0.48
3	O3SCORE	13.26	2.94	4.51	0.00
3	PRIOR	-0.41	0.34	-1.19	0.24
3	3RD DH AFLT	-0.19	0.71	-0.27	0.79
4	CONST	-2.13	2.34	-0.91	0.36
5	CONST	-11.66	4.09	-2.85	0.00
5	MA	0.82	0.55	1.48	0.14
5	JPME	0.50	0.79	0.63	0.53
5	NUKE	2.85	1.21	2.35	0.02
5	EAST	0.07	0.73	0.10	0.92
5	WEST	0.17	0.64	0.26	0.80
5	LEFT3	-0.41	0.71	-0.58	0.56
5	O3SCORE	10.97	4.40	2.50	0.01
5	PRIOR	0.39	0.57	0.68	0.49
5	3RD DH AFLT	0.63	1.06	0.59	0.56

Table 12. Reduced Model with no DC in Testing Significance of Explanatory Variables.

Regression	Variable Name	Coefficient	Standard Error	Standard Coefficient	*p* - value
1	CONST	-12.12	1.93	-6.28	0.00
1	DC	1.37	0.36	3.83	0.00
1	JPME	0.60	0.30	2.03	0.04
1	NUKE	0.16	0.33	0.49	0.62
1	EAST	-0.43	0.34	-1.27	0.20
1	WEST	-0.32	0.32	-1.00	0.32
1	LEFT1	-0.10	0.41	-0.24	0.81
1	O3SCORE	12.10	1.94	6.24	0.00
1	EARLY.ROLLER	2.23	0.70	3.18	0.00
1	PRIOR	-0.32	0.23	-1.42	0.16
1	3^{RD} DH AFLT	-0.16	0.67	-0.24	0.81
2	CONST	-2.62	3.63	-0.72	0.47
3	CONST	-11.58	2.76	-4.20	0.00
3	JPME	0.59	0.49	1.21	0.23
3	NUKE	-0.58	0.64	-0.91	0.37
3	EAST	-0.95	0.55	-1.74	0.08
3	WEST	-1.15	0.51	-2.27	0.02
3	LEFT2	-0.51	0.56	-0.90	0.37
3	O3SCORE	12.84	2.87	4.48	0.00
3	PRIOR	-0.43	0.35	-1.21	0.23
3	3^{RD} DH AFLT	-0.18	0.71	-0.25	0.81
4	CONST	-2.26	2.70	-0.84	0.40
5	CONST	-12.65	4.20	-3.01	0.00
5	JPME	0.61	0.76	0.80	0.42
5	NUKE	2.81	1.17	2.39	0.02
5	EAST	0.06	0.71	0.08	0.93
5	WEST	0.09	0.62	0.15	0.88
5	LEFT3	-0.35	0.71	-0.49	0.63
5	O3SCORE	12.62	4.43	2.85	0.00
5	PRIOR	0.37	0.56	0.65	0.51
5	3^{RD} DH AFLT	0.79	1.05	0.75	0.45

Table 13. Reduced Model with no MA Used in Testing Significance of Explanatory Variables.

Regression	Variable Name	Coefficient	Standard Error	Standard Coefficient	p -value
1	CONST	-12.92	1.97	-6.54	0.00
1	DC	1.36	0.36	3.80	0.00
1	MA	-0.55	0.22	-2.47	0.01
1	NUKE	0.18	0.33	0.54	0.59
1	EAST	-0.45	0.34	-1.34	0.18
1	WEST	-0.36	0.33	-1.11	0.27
1	LEFT1	-0.21	0.41	-0.51	0.61
1	O3SCORE	13.37	2.01	6.64	0.00
1	EARLY.ROLLER	2.05	0.72	2.87	0.00
1	PRIOR	-0.41	0.23	-1.80	0.07
1	3^{RD} DH AFLT	-0.10	0.67	-0.16	0.88
2	CONST	-2.40	2.97	-0.81	0.42
3	CONST	-11.59	2.78	-4.17	0.00
3	MA	0.07	0.33	0.22	0.82
3	NUKE	-0.62	0.64	-0.97	0.33
3	EAST	-0.93	0.55	-1.70	0.09
3	WEST	-1.16	0.51	-2.28	0.02
3	LEFT2	-0.57	0.56	-1.02	0.31
3	O3SCORE	12.81	2.94	4.36	0.00
3	PRIOR	-0.49	0.35	-1.40	0.16
3	3^{RD} DH AFLT	-0.11	0.71	-0.15	0.88
4	CONST	-1.28	1.15	-1.12	0.26
5	CONST	-11.55	4.07	-2.84	0.00
5	MA	0.85	0.55	1.55	0.12
5	NUKE	2.76	1.20	2.30	0.02
5	EAST	0.14	0.72	0.20	0.84
5	WEST	0.24	0.62	0.38	0.71
5	LEFT3	-0.39	0.71	-0.56	0.58
5	O3SCORE	10.83	4.37	2.48	0.01
5	PRIOR	0.33	0.56	0.59	0.55
5	3^{RD} DH AFLT	0.60	1.06	0.57	0.57

Table 14. Reduced Model with no JPME Used in Testing Significance of Explanatory Variables.

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